Upper Boundary Extension of the NASA Ames Mars General Circulation Model

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Introduction

- Extending the NASA Ames Mars General Circulation Model (MGCM) upper boundary will expand our understanding of the connection between the lower and upper atmosphere of Mars through the middle atmosphere.
- The extension's main requirements is incorporation of Non-local thermodynamic equilibrium (NLTE) heating (visible) and cooling (infrared).
- NLTE occurs when energy is exchanged more rapidly with the radiation field (or other energy sources) rather than collisions with other molecules.
- Without NLTE, above ~80km/~60km in Mars' atmosphere the IR/visible heating rates are overestimated.
- Currently NLTE has been applied successfully into the 1D RT code and is in progress for the 3D application.

1D Radiative Transfer Code

- RT code is based on two-stream approximation; quadrature in the visible, hemispheric mean in the IR
- Calculates fluxes at layer boundaries and at the surface; heating rates are calculated from these fluxes
- Includes CO_2 and H_2O gas opacity; aerosol optical properties for dust and water ice clouds
- Correlated-k gas opacities; calculated off-line on pressure and temperature grid
- Pressure ranges: 10^{-6} to 10^{+4} mbar (pressure at each grid point 10x larger than previous)
- Temperature ranges: 50 to 350 K, $\Delta T = 50$
- 12 spectral intervals (7 visible, 8 IR) with 17 Gauss points per interval
- IR spectral range: 1000 – 4.5 µm; Visible spectral range: 4.5 – 0.24 µm
- For more information about the RT code go to: http://spacescience.arc.nasa.gov/mars-climate-modeling-group/

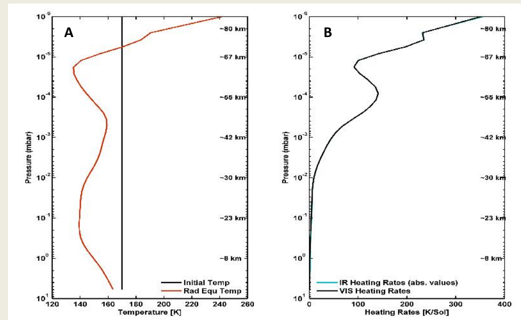
INITIAL CONDITIONS:

- Isothermal; 170 K
- Not connected to 3D model for initial testing
- Ptrop = 2E-6 mbar; 40 layers
- Surface pressure = 7 mbar; Albedo = 0.24, Dust free
- SZA = 80 degrees (for radiative equilibrium case)

Strategy for 1D RT code

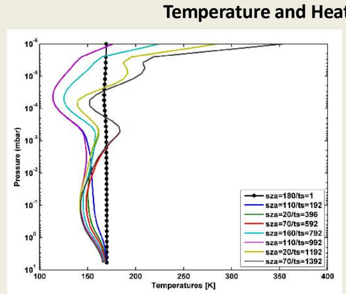
1) Extend tropopause pressure from 8E-4 mbar to 2E-6 mbar (to enter NLTE region)
2) Increase sigma layers from 24 to 40 (provide more resolution)
3) Implement NLTE additions
   a) Solar heating rate corrections from Table 1 in López-Valverde et al. (1998)
   b) CO_2 15 µm cooling parameterization adapted from Bougher et al. (2006)
4) Increase IR spectral bands from 5 bands to 8 bands
5) Check model to see if it goes to equilibrium and if it is stable

Radiative Equilibrium Temperature and Heating Rates

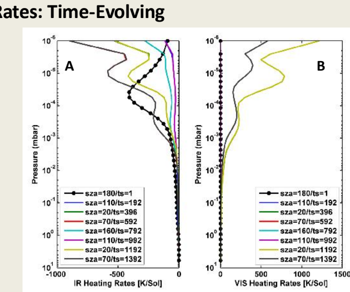


- Panel A represents a radiative equilibrium temperature profile (red line)
- The black line is the initial temperature profile.
- Panel B is the corresponding IR and Visible heating rates.

Temperature and Heating Rates: Time-Evolving



- Series of temperature profiles
- The RT code was time-evolved by cycling through SZA
- Each line represents a SZA at a specific timestep (ts)

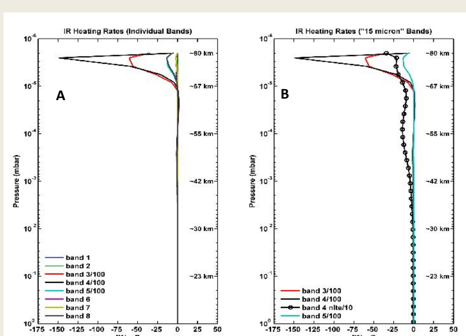


- Panel A is the corresponding time evolving IR heating rates and panel B is the corresponding Visible heating rates

IR Spectral Bands

Band	Wavelength (µm)	
1	1000.0 – 33.3	
2	33.3 – 18.2	
3	18.2 – 15.7	Wing of 15 micron CO_2 band
4	15.7 – 14.2	Core of 15 micron CO_2 band
5	14.2 – 12.9	Wing of 15 micron CO_2 band
6	12.9 – 10.3	12 micron water ice band
7	10.3 – 7.8	9 micron dust band
8	7.8 – 4.5	

Radiative Equilibrium IR Heat Rates



- All LTE band are represented in panel A (bands 3-5 are scaled by 100)
- Bands 3-5 are replaced with the corrected NLTE 15 micron heating rates (these bands are shown in panel B)

Conclusion/Future Work

- Adding NLTE provides smaller heating rates; which is the expected result
- 1D RT code does come to equilibrium and it is stable when evolved in time
- More analysis is needed for the upper boundary
- These 1D RT code updates will be implemented into the 3D code
- Analysis of MGCM results with the vertical extension and NLTE are still in progress

- Sample of 3D IR heating rates
- 5 spectral bands (not comparable to other results on poster)
- Microphysics off
- Constant dust everywhere with a visible dust optical depth = 0.3 and Conrath-v = 0.03
- Cold start; 100 sol runs (Ls=50 to Ls=90)
- Output: zonally averaged over 10 sols